FINAL

MONK HILL TREATMENT SYSTEM INSTALLATION REPORT ADDENDUM

LINER REMOVAL, EVALUATION AND REPAIR OF WINDSOR WELL (NO. 48) AND WELL 52

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ACRONYMS AND ABBREVIATIONS

AWWA	American Water Works Association
bgs	below ground surface
btoc	below top of casing
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CITM	casing inspection thickness measurement
DSAL	dual swab airlift pumping
E-C	erosion-corrosion
gpm	gallons per minute
JPL	Jet Propulsion Laboratory
MHTS	Monk Hill Treatment System
NASA	National Aeronautics and Space Administration
O.D.	outside diameter
OEAL	open end airlift
ppm	parts per million
PVC	polyvinyl chloride
PWL	pumping water level
PWP	Pasadena Water and Power
RD/RA	Remedial Design/Remedial Action
RPM	Remedial Project Manager
VOC	volatile organic compound

1.0 INTRODUCTION

Beginning in July 2009 and extending through January 2011, well rehabilitation was performed at four Pasadena Water and Power (PWP) production wells: Arroyo Well, Ventura Well, Windsor Well, and Well 52. Well rehabilitation activities were performed in accordance with the 2009 Remedial Design/Remedial Action (RD/RA) Work Plan.[1] The four production wells supply groundwater to the City of Pasadena-operated Monk Hill Treatment System (MHTS). The MHTS removes volatile organic compounds (VOCs) and perchlorate from groundwater extracted from the production wells and is implemented as a remedial action under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) program at the National Aeronautics and Space Administration's (NASA's) Jet Propulsion Laboratory (JPL).[2] Figure 1 presents the location of the JPL facility, PWP production wells, and MHTS. Completion of the MHTS construction and well rehabilitation activities were documented in the August 2011 MHTS Installation Report[3].

Following rehabilitation activities, Windsor Well and Well 52 experienced liner failure, allowing engineered gravel pack to enter the well casing and screen. In the summer of 2011, the gravel pack and liners were removed from both of the wells, and the liners were evaluated to determine the cause of the failure. The evaluation determined that the liner failure was due to unforeseen site conditions that led to high, localized flow velocities with entrained sand (technically referred to as erosion-corrosion [E-C]) forming holes and abrasions in the liners and screens. In December 2011, a corrective action plan was presented to the stakeholders to repair and return the two wells to service. In the summer of 2012, the corrective action plan was implemented, with re-fabricated liners and re-conditioned pumps installed into the wells. This document serves as an addendum to the aforementioned August 2011 MHTS Installation Report and documents the liner removal, evaluation, and the liner and pump reinstallation at Windsor Well and Well 52.

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[1] NASA. 2009. *Remedial Design/Remedial Action (RD/RA) Work Plan for the Monk Hill Treatment System (MHTS),* National Aeronautics and Space Administration Jet Propulsion Laboratory, Pasadena, California. March.

[2] NASA. 2007. *Interim Record of Decision for Operable Unit 3 Off-Facility Groundwater,* National Aeronautics and Space Administration Jet Propulsion Laboratory, Pasadena, California. July.

[3] NASA. 2011. *Operable Unit 3 Monk Hill Treatment System Installation Report,* National Aeronautics and Space Administration Jet Propulsion Laboratory, Pasadena, California. August.

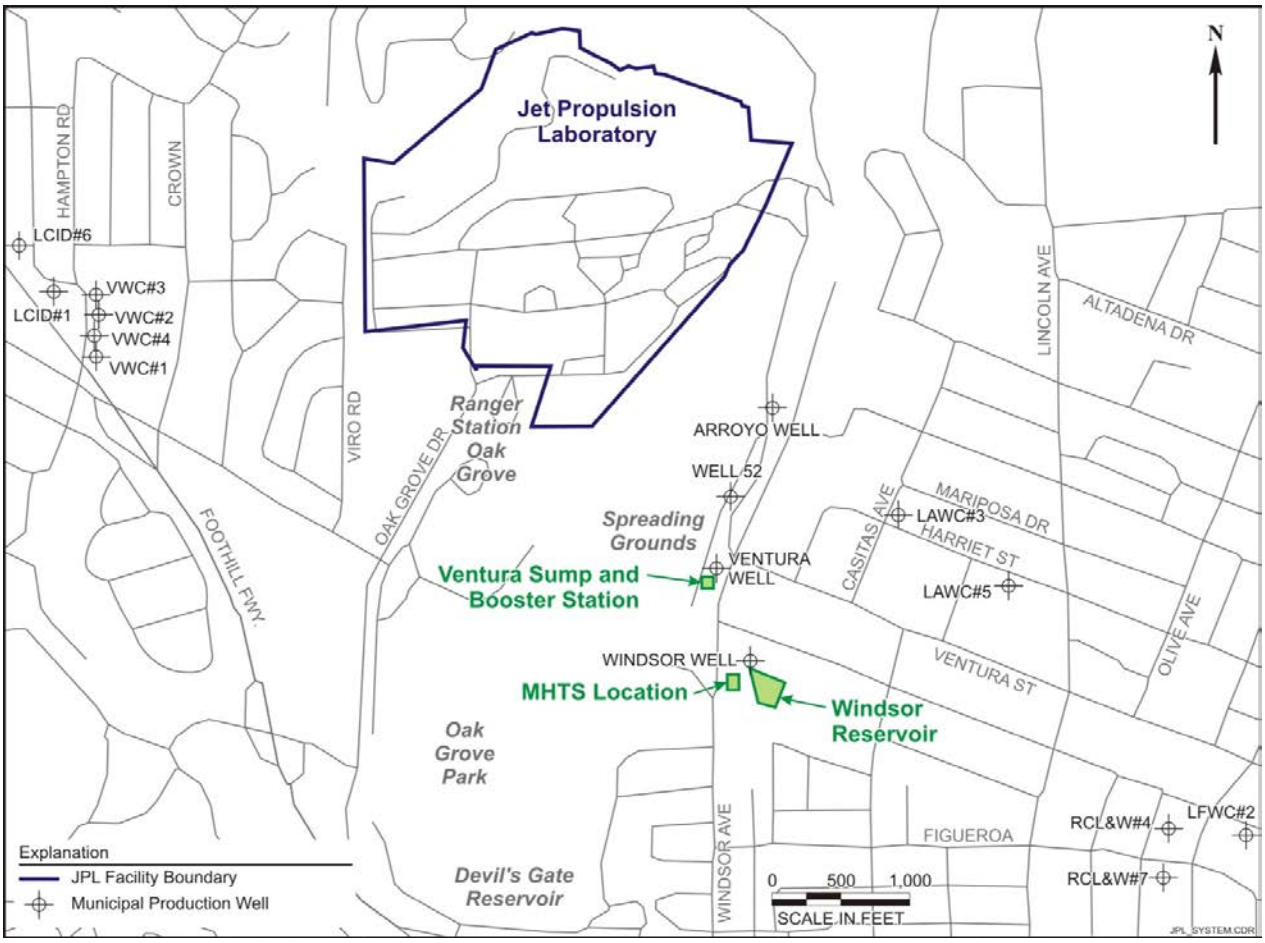

Figure 1. MHTS Site Overview

2.0 WINDSOR AND WELL 52 LINER DAMAGE BACKGROUND

The Windsor Well (No. 48) and Well 52 are 600-foot deep and 647-foot deep drinking water production wells, respectively, owned by PWP. The Windsor Well was constructed in 1969 and Well 52 was constructed in 1977. The original Roscoe Moss well construction logs are presented in Attachment 1 and the original well completion diagrams are presented in Attachment 2. Operation was ceased at both wells in January 2002 due to the presence of perchlorate in groundwater. Rehabilitation activities were performed on the wells by Battelle, under contract to NASA, beginning in July 2009 and extending through December 2010 (Windsor Well) and January 2011 (Well 52). Activities included mechanical and chemical cleaning of the original well casing followed by the installation of a liner and engineered gravel pack. Liner diagrams are presented in Attachment 3 and liner installation summaries are presented in Attachment 4. New pumps were installed in the wells following pump development and testing. Well rehabilitation activities were presented in the August 2011 MHTS Installation Report.[3]

2.1 Windsor Well Performance Issues

The first well to experience performance issues was the Windsor Well. In late December 2010, after 290 hours of pumping and the extraction of 22.3 million gallons of water, the pump automatically shut down due to gravel pumping. After pump removal, review of a video log determined that there was a circular hole in the blank casing of the liner (see Figure 2). Subsequently, a 4-foot long "squeeze" patch was installed to repair the hole (see Figures 3 and 4).

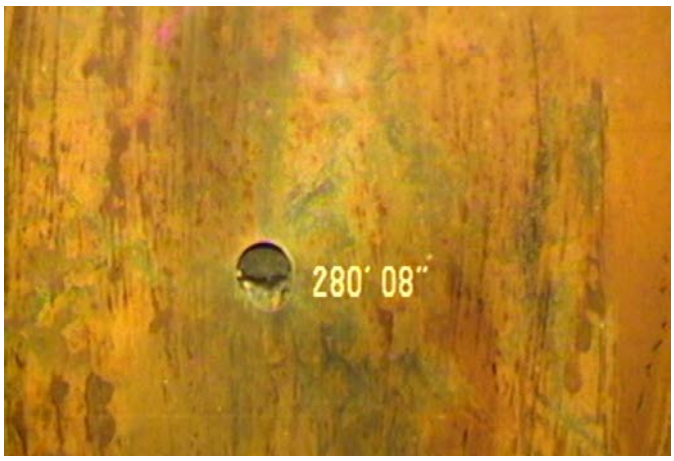

Figure 2. Hole in Windsor Liner Approximately 9 months after Installation (video log completed on January 14, 2011)

Figure 3. "Squeeze" Patch before Installation into the Windsor Well (January 15, 2011)

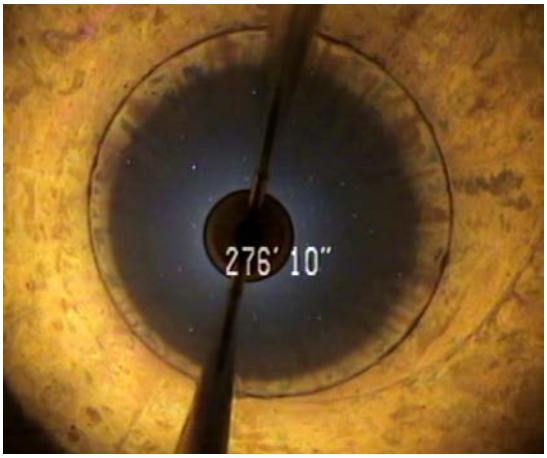

Figure 4. Top of 4 foot long Patch Installed in Windsor Liner (Video log completed on January 17, 2011)

The well was returned to operation, and after 199 hours of pumping and extraction of 15.9 million gallons of water, gravel pumping recurred, and the pump was again removed from the well. Review of a video log determined that there was a hole in the patch (see Figure 5) at the same location of the first hole. Subsequent inspection of Windsor's pump column identified an abrasion on the column pipe at the same depth of the hole in the liner and patch (Figures 6, 7, and 8).

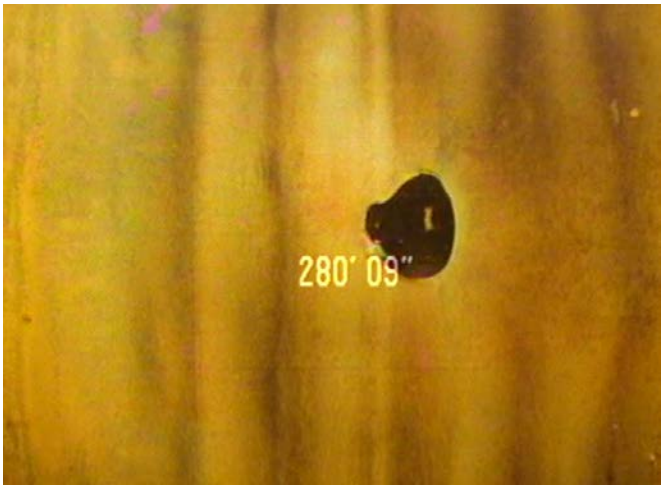

Figure 5. Hole in Windsor's Liner Patch (Video log conducted on February 12, 2011)

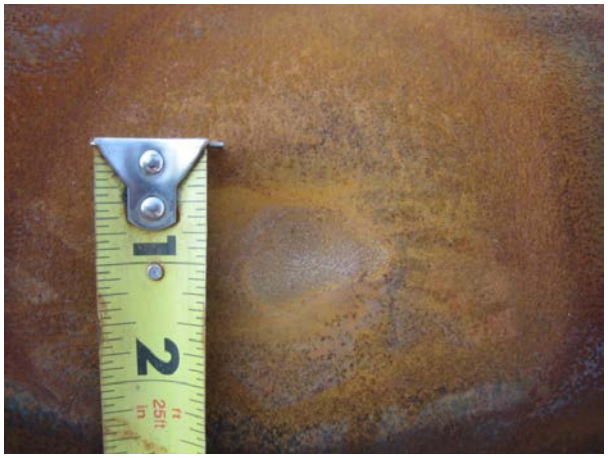

Figure 6. Abrasion on Windsor Pump Column at 280.67 ft bgs

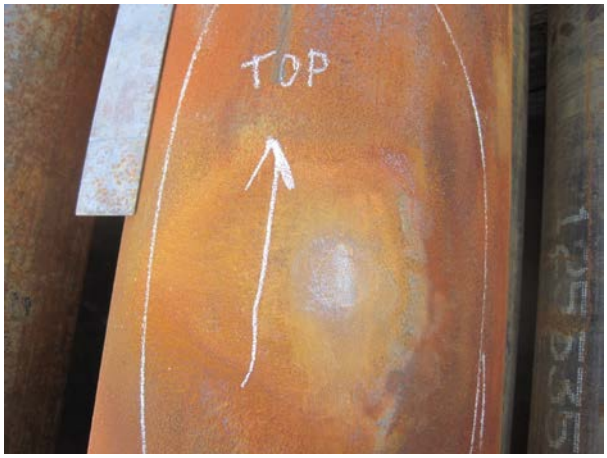

Figure 7. Abrasion on Windsor Pump Column at 280.67 ft bgs

Figure 8. Windsor Pump Column with Indentation Identified with Chalk Circle

On March 9 and 14, 2011, Pacific Surveys performed a video log, static spinner log (non-pumping), temperature/noise log, and a casing inspection thickness measurement (CITM) tool log. The video log (see Attachment 5) showed flow emanating from the hole observed in the liner's blank casing; however, the flow was not significant enough to puncture a hole in the casing under non-pumping conditions. At 280.00 feet below ground surface (bgs) the flowmeter responded to a horizontal low flow component (i.e., < 3 counts per second), but not a vertical component. It was noted that flow entered the well around 320.00 feet (first perforations) and had down flow to around 520.00 feet bgs. The temperature log indicated a geothermal gradient from 240.00 feet to the flow emanating from the first set of perforations at 320.00 feet. From 320.00 feet down to the last set of perforations, an isothermic response was recorded, indicating water moving from one zone to another. At 280.00 feet there was only a horizontal temperature response

due to the flow emanating from the hole. Next, a noise log, which uses a high fidelity quartz transducer that can record sound within the water column, was completed. If there is a pressure change due to water or gas flow, the device will record this disturbance. A slight, but insignificant change in the noise log response was observed at 280.00 feet. Lastly, the CITM device was used to measure the wall thickness of both the 14.50-inch and 20-inch diameter casings. The original 20-inch diameter casing appeared to be in good condition with the exception of possible spalling or flaking of the casing at 150.00 feet and 210 feet. The investigation data from Pacific Surveys are presented in Attachment 6.

2.2 Well 52 Performance Issues

Well 52 was operated from late January 2011 until late May 2011 when gravel pack measurements determined that a large volume of gravel pack was missing from the annular space between the liner and original casing. The pump was pulled from the well on May 26 and May 27, 2011 (see Figure 9) and a video log was completed on June 1, 2011; the video log showed some thinning in the well screen at 288.83 ft bgs (see Figure 10), and the well contained 143 ft of gravel pack and formation material.

Figure 9. Well 52 Pump Removal (May 26, 2011)

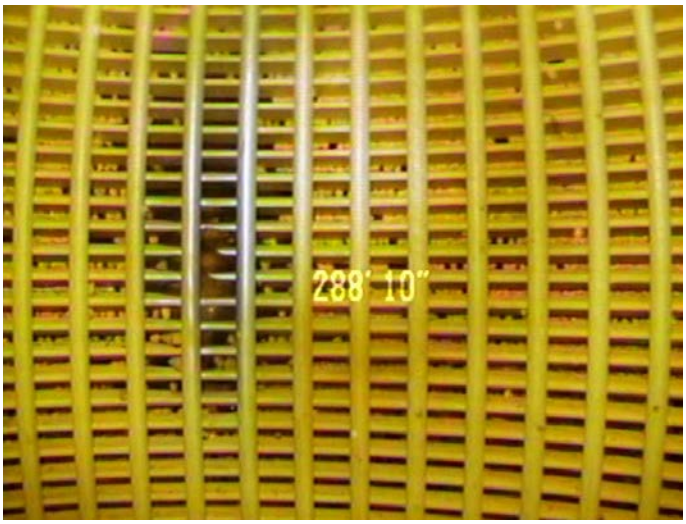

Figure 10. Well 52 Thinning of Liner Screen at 288.83 feet btoc (June 1, 2011)

The fill was removed from the well on June 8 and June 9, 2011 via open end airlift (OEAL) pumping, and the well was video logged on June 13, 2011. The results of the video log determined that there was a hole in the blank casing at 224.58 ft bgs and thinning/holes in the screen at 288.83 ft, 484.67 ft, 515.08 ft, and 526.50 ft bgs.

On June 16, 2011, Pacific Surveys performed a non-pumping spinner log of the well (see Attachment 6), and on June 17, 2011, the well contractor brushed the entire screened zone with a nylon bristle brush to clean the screen slots in preparation for another video log. A post-brush video log was performed by Pacific Surveys on June 20, 2011, and confirmed the previous liner hole locations at 221.40 ft in the blank casing (see Figure 11), and in the screen at: 285.00 ft (Figure 12), two holes at 480.80 ft (Figures 13 and 14), 498.30 ft (Figure 15), 511.00 ft (Figure 16), and 522.20 ft (Figure 17). Please note that Pacific Surveys used the top of liner instead of top of flange as a reference point during the video log, so the depths are different as compared to the previous video logs.

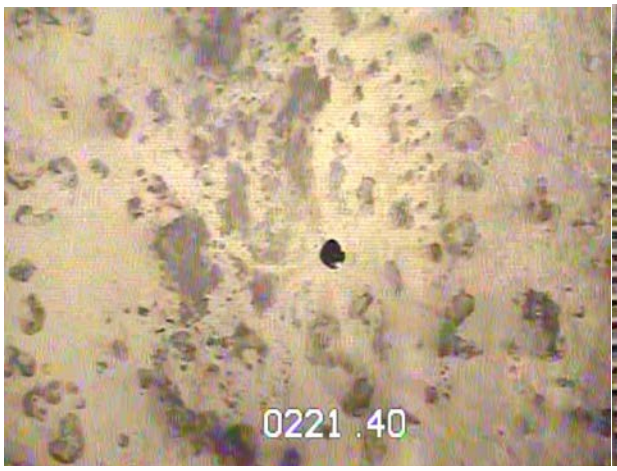

Figure 11. Well 52 Hole in Liner Blank Casing

Figure 12. Well 52 Hole in Liner Screen

Figure 13. Well 52 Hole in Liner Screen

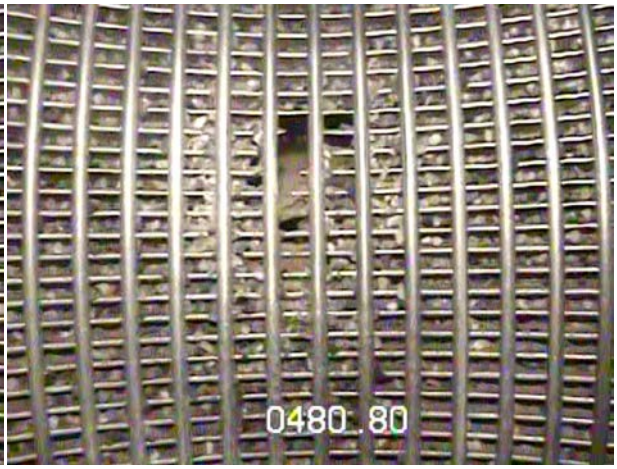

Figure 14. Well 52 Another Hole in Liner Screen at 480.80 ft

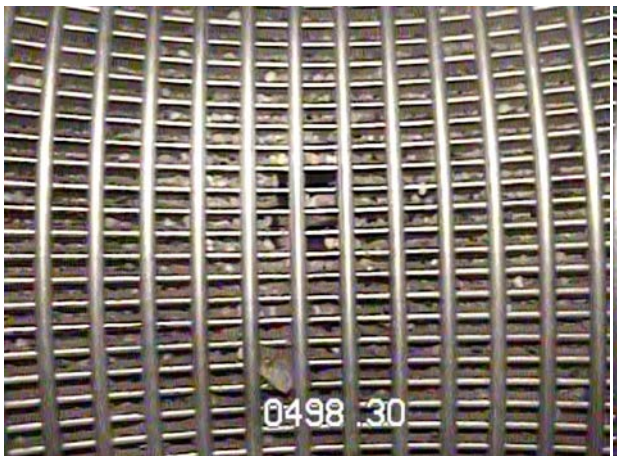

Figure 15. Well 52 Hole in Liner Screen

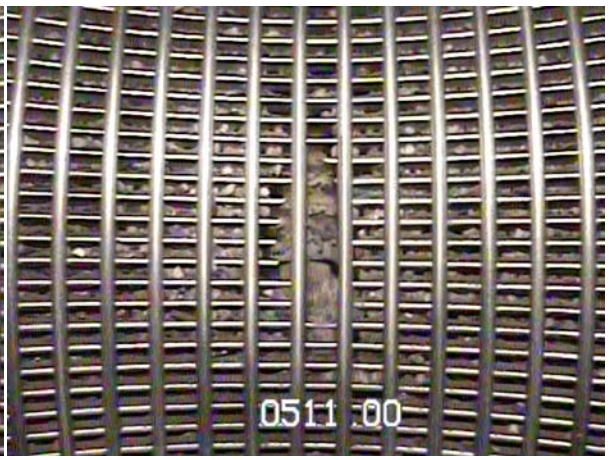

Figure 16. Well 52 Hole in Liner Screen at 511.0 ft; Original Well Casing Perforation Visible through Hole in Liner Screen

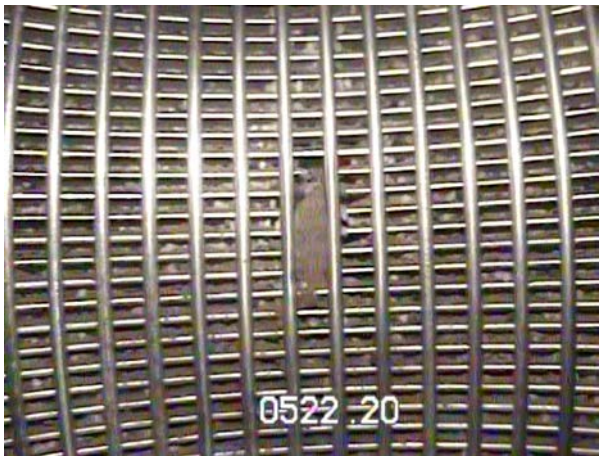

Figure 17. Well 52 Hole in Liner Screen

After considering the state of both well liners, the stakeholders requested that the liners be removed from both Windsor Well and Well 52. Due to the escalating risks, liability, and costs related to the liner removals, legal negotiations ensued between Battelle and its well rehabilitation contractor. The well liners were removed from the wells during August 2011 followed by independent evaluations by the well contractor, Battelle, and a third-party consultant.

2.3 Windsor Well Liner Removal

Beginning on August 3, 2011, the well contractor began the Windsor Well liner removal activities. The general procedure was as follows: the liner's screen was cut and/or perforated with a mills knife cutting tool to allow the gravel pack to flow into the liner. Once gravel pack flowed into the liner, it was removed from the well with an OEAL pumping tool. The mixture of water and gravel pack was discharged into a roll-off bin, and the water was pumped from the bin back down into the annular space between the original casing and the liner to facilitate gravel pack pumping. A video log was completed on August 8, 2011 to check if the mills knife cutting tool was successfully cutting the wire-wrapped screen. The mills knife

created a crease in the screen, but did not damage it enough to allow gravel pack to enter the liner. After completing the video log, five perforations were made in the bottom of the screen, and the gravel was removed via OEAL pumping. On August 12, 2011, additional mills knife perforations were made at 590 ft, 586 ft, and 582 ft below top of casing (btoc). The gravel was removed via OEAL pumping. The liner was successfully lifted from the well beginning on August 19, 2011, and cut into 20-foot long sections with a cutting torch. Each section was stamped with the section number (i.e., 1 through 31) on the north side of the liner and just below the top of the liner section. These sections were placed on four by fours at the ground surface, measured, inspected, photographed, and then loaded onto a pipe truck to be transported to the well contractor's facility for further inspection. By the end of the day on August 19, 2011, section number 15 (i.e., 280 to 300 feet btoc section) of the liner was hoisted to the surface. At this time, the holes in the liner and patch were observed at ground level and are presented in Figures 18 and 19.

Figure 18. Hole in Liner and Patch Observed during Liner Removal (August 19, 2011)

Figure 19. Close-up of Hole in Windsor's Liner and Patch (August 19, 2011)

Figure 20 shows the removal of the screen section and torch cutting of the liner joints. On August 22, 2011, all 31 sections of the liner were successfully removed from the Windsor Well. Figure 21 shows the bottom of the liner being hoisted from the Windsor Well. Figure 22 shows liner screen section numbers (from left to right) 27, 28, 29, 30, and 31 placed on four by fours. Section 31 was intentionally damaged with the mills knife cutting tool to facilitate gravel pack removal during airlift pumping activities.

Figure 20. Welder Torch Cutting Windsor Well Liner Joint

Figure 21. Windsor Liner Successfully Removed from Well (August 22, 2011)

Figure 22. Windsor Liner Screen Section; Shows Mills Knife Damage to Screen for Gravel Removal

A liner removal work summary is provided in Attachment 7 documenting daily activities. On August 26, 2011, a video log was completed after the liner was removed from the well to inspect the original well casing. The video log identified a small hole at a joint in the original blank casing at a depth of 280.50 ft

btoc (see Figure 23). A copy of the video log well inspection report is included in Attachment 5. Figure 24 presents a liner damage diagram in which the hole in the liner's blank casing is identified.

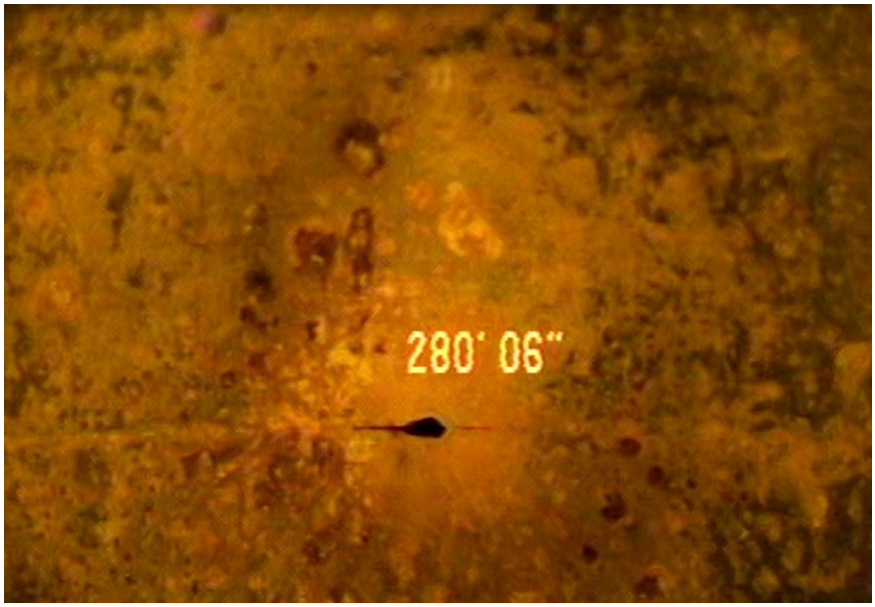

Figure 23. Hole in the Windsor Well's Original Blank Casing Located at Joint (Post-Liner Removal; August 26, 2011)

Battelle

Liner Damage Diagram
Pasadena, California
WINDSOR-48

State Well ID#: 1910124-022	Site: City of Pasadena (MHTS)	Well #: WINDSOR-48	Northing: 1892155.945
Rehabilitation Contractor: Layne Christensen	Well/Liner Diameter: 20.00-inch/14.50-inch	Liner Install Dates: 4/12/10 - 4/16/10	Easting: 6511051.010
Geologist: D. Conner	Installer/Welder: M. Evans/G. Frias	Liner Removal Dates: 8/3/11 - 8/22/11	Surface Elevation: 1153.86'

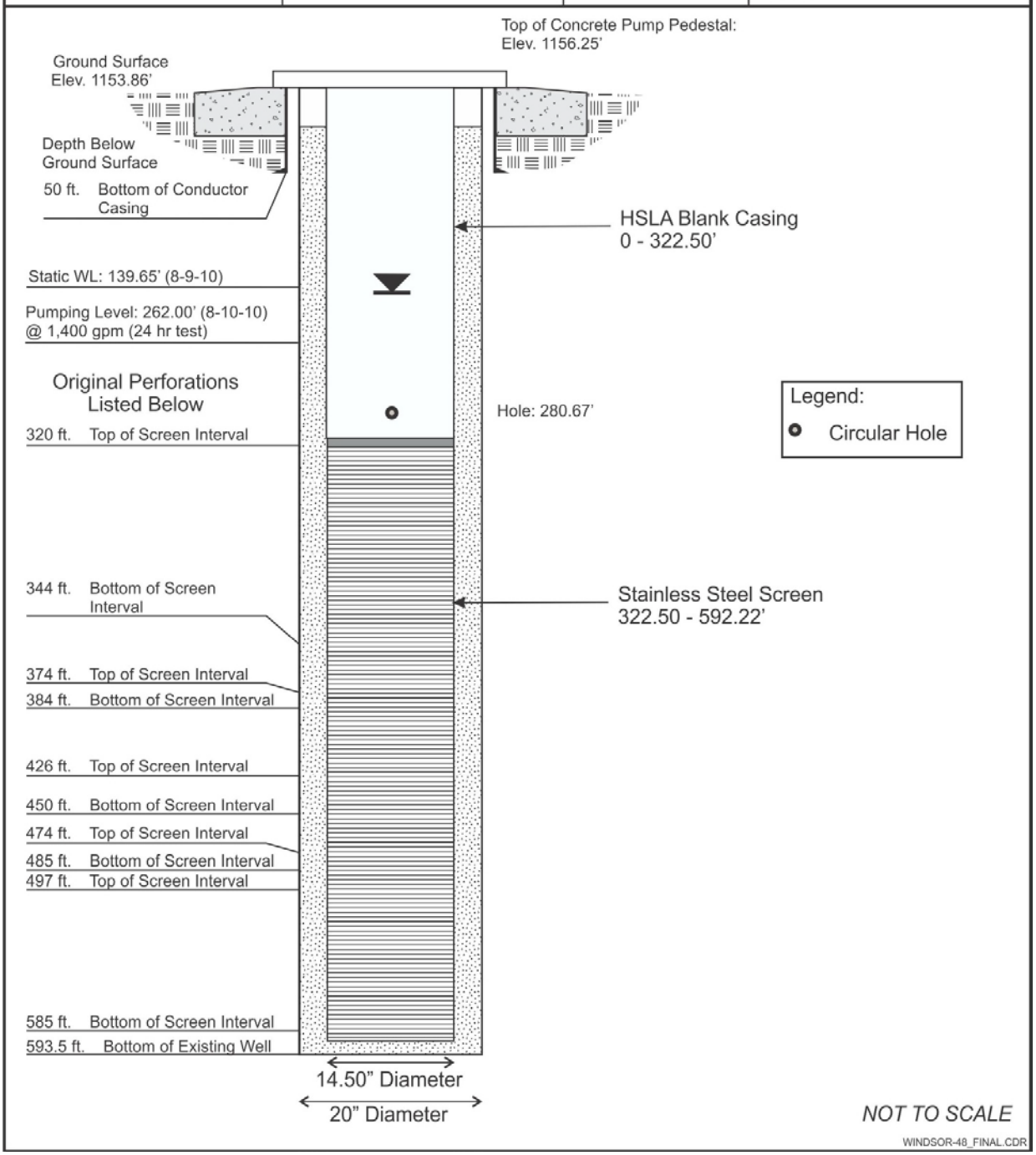

Figure 24. Liner Damage Diagram

2.4 Well 52 Liner Removal

Beginning on August 3, 2011, the well contractor began Well 52 liner removal activities. Liner removal was completed by the same procedure as was described in the Windsor Well removal section above. A video log was completed on August 15, 2011 to check if the mills knife cutting tool was successfully cutting the wire-wrapped screen. Mills knife damage was noted at 605 ft btoc in the liner's screen. A copy of the video log well inspection report is included in Attachment 5. Once the gravel pack was removed from the well, the liner was hoisted from the well and torch cut into 20-foot long sections (see Figure 25).

Figure 25. Well 52 Torch Cutting Blank Section of Liner

Each section was stamped with the section number (i.e., 1 to 32) on the north side of the liner and just below the weld. These sections were placed on four by fours at the ground surface, measured, inspected, photographed, and then loaded onto a pipe truck and transported to the well contractor's facility for further inspection. The following series (i.e., Figures 26 through 37) of photographs shows the abrasions and holes in the liner that were identified during liner removal (A liner removal summary is presented in Attachment 7). Figure 38 presents a liner damage diagram in which the hole in the liner's blank casing and holes/abrasions in the liner's screen are identified.

Figure 26. Well 52 Hole in Blank Section of Liner Casing at 220.75 ft (Joint #12)

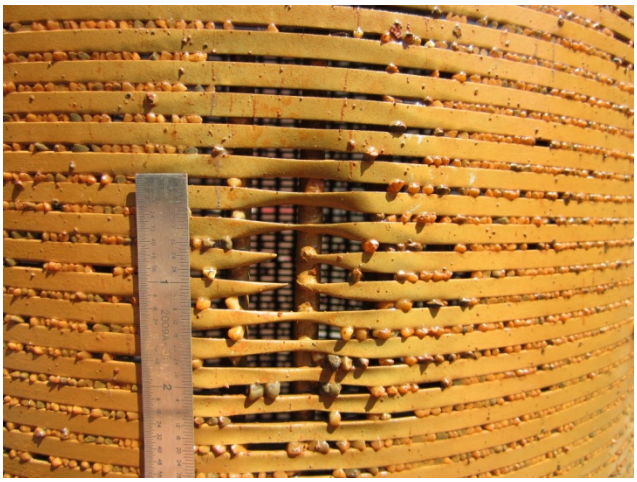

Figure 27. Well 52 Hole in Liner Screen Section

Figure 28. Hole in Liner Screen on Right 284.14 ft. Abrasions on Left Side of Photo

Figure 29. Abrasion in Liner Screen at 379.20 ft (Joint #21)

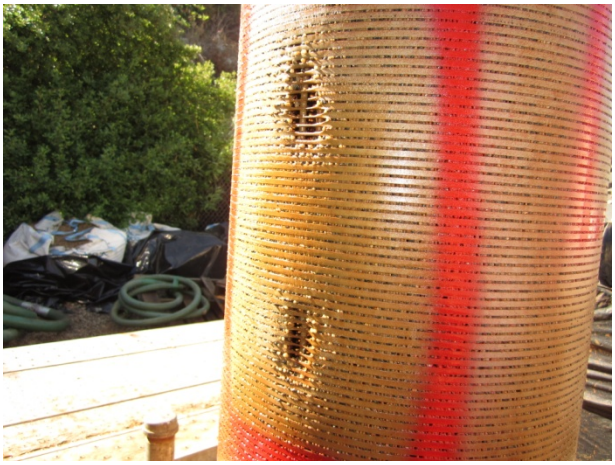

Figure 30. Holes at 478.5 ft and 479.25 ft (Joint #26)

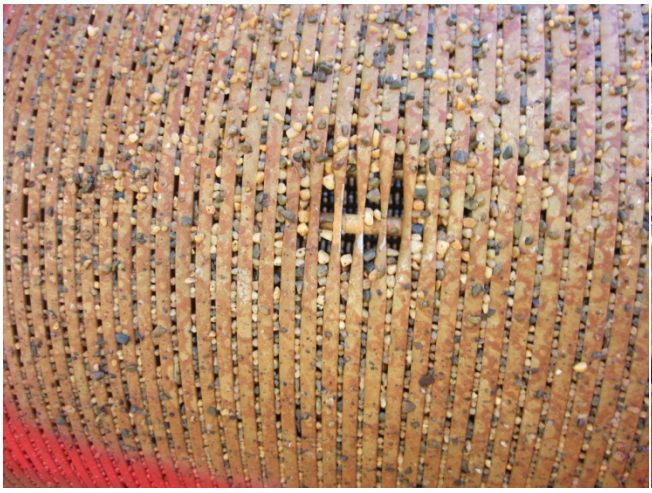

Figure 31. Hole at 496 ft (Joint #27) Impacted Gravel Due to Airlift Pumping

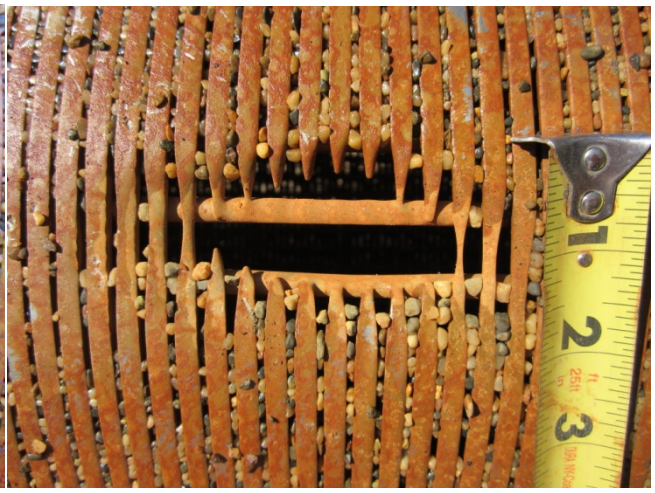

Figure 32. Hole at 508.75 ft (Joint #27)

Figure 33. Holes at 519.90 ft and 521.50 ft (Joint #28)

Figure 34. Close-up of Hole on Joint #28

Figure 35. Joint #32 Intentionally Damaged by Mills Knife

Figure 36. Well 52 Liner Successfully Removed from Well

Figure 37. Well 52 Liner Screen from Left to Right: #32 - #23

Battelle

Liner Damage Diagram
Pasadena, California
WELL-52

State Well ID#: 1910124-021	Site: City of Pasadena (MHTS)	Well #: WELL-52	Northing: 1893789.615
Rehabilitation Contractor: Layne Christensen	Well/Liner Diameter: 20.00-inch/16.63-inch	Liner Install Date: 10/6/10 - 10/11/10	Easting: 6510947.930
Geologist: D. Conner	Installer/Welder: M. Evans/G. Frias	Liner Removal Dates: 8/3/11 - 8/18/11	Surface Elevation: 1076.76'

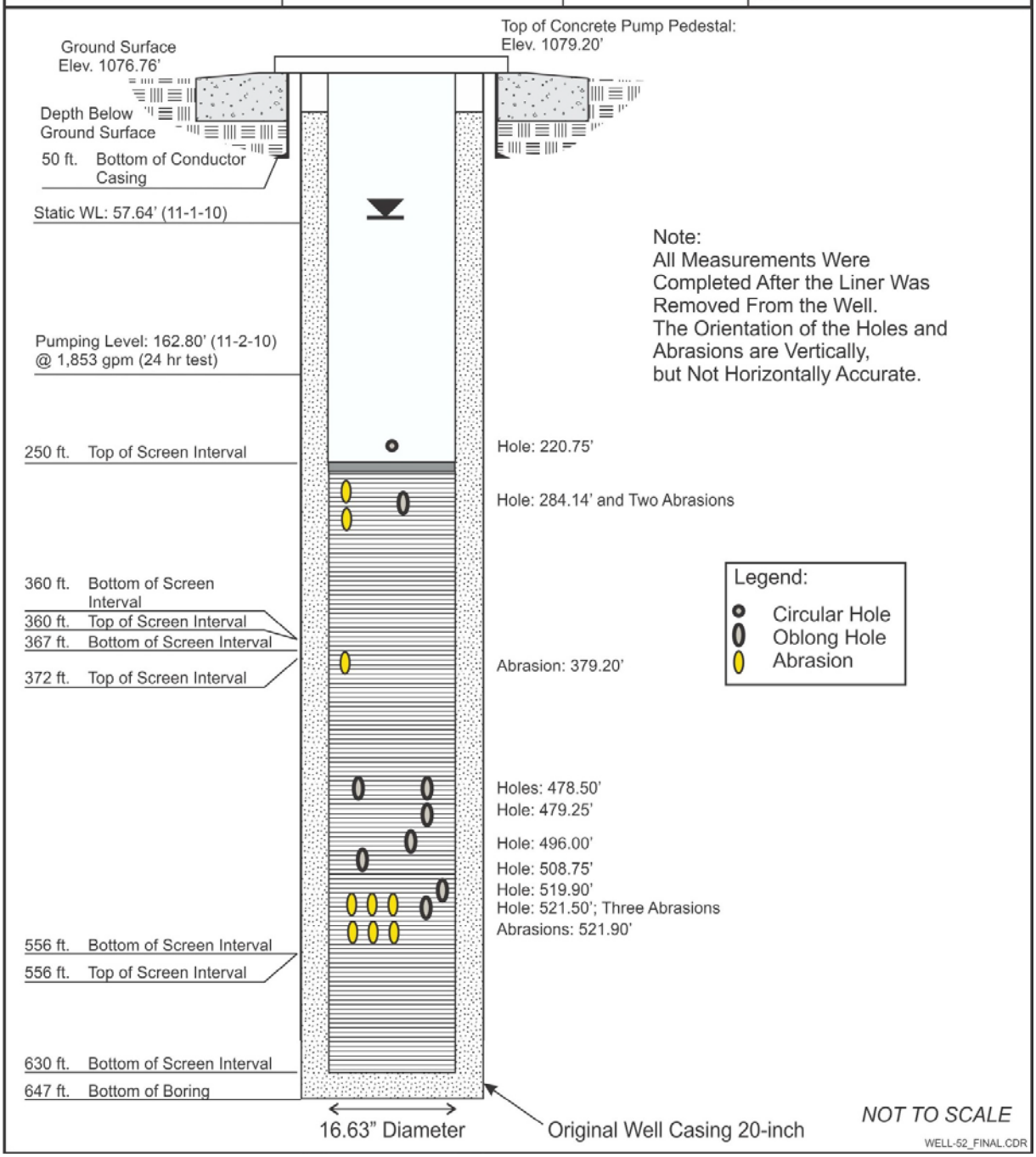

Figure 38. Liner Damage Diagram

3.0 LINER DAMAGE EVALUATION AND REMEDY

From late August 2011 through December 2011, a review of all available data and records was performed, which included: original Roscoe Moss Company well construction and lithologic logs; PWP well diagrams; downhole logs (e.g., video, dynamic and static spinner logs, CITM, noise and temperature); water chemistry analytical reports; first and second stage rehabilitation (i.e., mechanical and chemical cleaning) procedures, liner and gravel pack installation procedures; Roscoe Moss Company liner solid casing and screen material quality control and assurance information, bills of lading, metallurgical and materials test reports; mechanical sieve analyses (native formation and engineered gravel pack); well development field log sheets and field notes; pump test data sheets; photo records of liner installation and subsequent removal; and lastly the well contractor's evaluation report. In addition, the technical team reached out to water well industry experts, and enlisted the expertise of a third-party hydrogeological consulting firm.

The review determined the following root causes of liner failure:

Windsor

- Review of the post-liner removal video log confirmed that a hole at a welded joint in the original casing allowed water to flow with sufficient velocity to entrain sand and form a hole in the well liner through E-C. This same condition caused the hole in the "squeeze patch" to form and created the indentation on the pump column.
- The hole in the original casing was not within a production zone (i.e., perforated zone) of the original well and was therefore not an interval of interest to be inspected during the pre-liner video log. Even so, if the hole had been identified during the pre-liner video log, the normal course of action would have been to install a liner, which is ultimately what was done.

Well 52:

- The holes that developed in the slotted wire-wrap screen portion of the liner were caused by E-C.
- The gravel lodged in the screen removed from Well 52 most likely occurred during the airlifting of the gravel from inside the screen not because the gravel was undersized for the 0.070-inch slot size screen used in Well 52.

3.1 Well 52 Evaluation Details

In addition to the root causes presented above, the third-party reviewers noted the following:

- The holes that developed in the slotted wire-wrap screen portion of the liner in Well 52 allowed the gravel pack in the annular space to enter the well screen so that it filled the bottom 143 feet of the well screen.
- The gravel lodged in the screen removed from Well 52 most likely occurred during the airlifting of the gravel from inside the screen not because the gravel was undersized for the 0.070-inch slot size screen used in Well 52.
- There seemed to be a correlation (within a couple of feet) of enlarged or open perforations in the original 20-inch casing in Well 52 with the holes in the liner screen.
- Small holes that developed in the original casings in Well 52 can apparently result in velocities and sand entrainment that are sufficient to create E-C conditions to the point that the liner casings developed holes.
- Because of the effective reduction of open perforations in the 20-inch casing in Well 52 due to incrustation, the flow velocity through the remaining open perforations should be higher.

- The total sand production measured during the 24-hour pumping test in Well 52 was an average over the total volume of water pumped from the well, and individual zones or perforations in the 20-inch screen could produce significantly higher sand concentrations.
- Based on the photographs, the holes and abrasions in the screen and casing in Well 52 appear to be from E-C. Further, the failure of the screen was identified as being due to E-C, based upon the morphology and location of the attack (thinning of the ribs of the screen in an enhanced flow zone).
- The E-C rate is considered to be greatly enhanced by the presence of formational sand in the water flow through the gravel bed and through the screen, such that sand impact on the screen ribs breaks down the passive film on the Type 304 SS, resulting in an enhanced dissolution rate of the steel (i.e., in enhanced E-C). From the data made available, it is not possible to ascertain whether the prevailing chloride level in the water (approx. 70 parts per million [ppm]) exacerbates the observed E-C of the steel, but it is known that chloride ion induces passivity breakdown on stainless steel, even at this low concentration,[4] so that it is assumed to be a significant factor.
- The composition of the steel corresponds to the Type 304 austenitic grade, with no discrepancies or unusual characteristics being noted that would predispose the steel to enhanced E-C rate.
- The water composition is typical of groundwater and does not indicate any condition that would predispose the steel to enhanced E-C, except for the presence of chloride ion, as noted above.
- Although no measured velocities at individual perforations in Well 52 exist, it seems reasonable to assume that velocities and sand entrainment were sufficient to create E-C conditions to the point that screen failure occurred in the liner. Because of the lack of definitive data, it has been possible to only estimate an approximate value for the flow velocity of the sand-laden water past the screen. However, the value obtained (approximately 1 m/s) lies within the range reported by the American Water Works Association (AWWA) for E-C in screens for other water supply wells.

The well contractor claimed that the cause of the issues was not a result of workmanship or materials, but rather unforeseen site conditions associated with high flow velocities and entrained sand which appeared to be substantiated by their reports, Battelle's evaluation, and input from third-party experts. Specifically:

- The well contractor performed multiple industry standard well rehabilitation techniques to clean the casing and perforations to facilitate groundwater flow from the formation into the wells. These activities included typical and advanced techniques: open ended and dual-swab airlift pumping, brushing, swabbing, chemical cleaning, carbon dioxide injection, and nitrogen bursting.
- The well contractor installed liners and the gravel pack that were designed to prolong the lifespan of the wells and provide structural integrity. The engineered gravel pack and liner screen slot size were properly sized.
- At no time prior to or during the well rehabilitation activities did data indicate that a jetting or E-C existed in either of the wells.
- The well contractor achieved the production goals of 1,400 and 1,800 gallons per minute (gpm) for Windsor Well and Well 52, respectively, and sand-free water during performance testing.

3.2 REPAIR REMEDY

In December 2011 (modified in January 2012), the team proposed technical approaches to return both Windsor and Well 52 to service, which were deemed technically sound, had the lowest risk of catastrophic well failure, and had the highest likelihood of success based on the available information. The team did not recommend additional perforations be installed to the existing well casing due to the risks associated with

[4] Macdonald,D.D. 1999. "Passivity: Key to Our Metals-Based Civilization", *Pure Applied Chemistry*, 71, 951.

this option: potential well failure, damage to the casing preventing the installation of the liner, and the potential for excessive sand production through the newly installed perforations. The stakeholders agreed to the proposed technical approach summarized in Table 1 below, and a notice to proceed was issued in July 2012.

Table 1. Technical Approaches to Return Windsor Well and Well 52 to Service

Windsor Well	**Well 52**

Technical Approach:
• Liner re-fabrication/cleaning
  o Damaged section of liner will be replaced;
  o Torch-cut ends of pipe will be straightened and re-beveled;
  o Material will be cleaned
• Brush and bail original well casing(1)
• Liner and gravel pack reinstallation
  o Liner material will be lowered into well and welded at 20-foot intervals;
  o Engineered gravel pack will be placed in annular space between original well casing and liner to a depth of 300 feet
• Gravel pack consolidation and well development by dual swab airlift pumping(1)
• Installation of gravel fill tube followed by 3 to 5 foot transition sand placed on top of gravel pack
• Installation of 300-foot long cement seal from top of transition sand to ground surface
• Final video log(1)
• Well disinfection
• Rebuilt pump installation
• Bacteriological sampling
• Resume operation to MHTS
	Technical Approach:
	• Liner re-fabrication/cleaning
	  o Damaged section of liner will be replaced;
	  o Torch-cut ends of pipe will be straightened and re-beveled;
	  o Material will be cleaned
	• Brush and bail original well casing(1)
	• Liner reinstallation (without gravel pack)
	  o Liner material will be lowered into well and welded at 20-foot intervals;
	• Final video log(1)
	• Well disinfection
	• Rebuilt pump installation
	• Bacteriological sampling
	• Resume operation to MHTS

Advantages: • Cement seal should plug hole in original blank casing, and alleviate jetting/E-C condition. • Production goals and sand-free water should be achieved. **Disadvantages/Risks:** • Some perforations may be plugged in original well casing, which could lead to jetting/E-C condition and potential liner failure similar to Well 52. Extra annular space relative to Well 52 is of benefit. • Liner will be permanently cemented into place and cannot be removed in the future. • If problems develop, then well replacement may be necessary; current cost estimates for a new well are at approximately $3M (including drilling, installation, development, and associated infrastructure improvements).	**Advantages:** • Installation of liner will provide an added level of security and structural integrity to the original well casing. • Production goals and sand-free water should be achieved. Flow capacity of the well may actually increase with no gravel pack to impede flow. • Liner is removable since it is not cemented in place. • Need for storage and treatment of large volumes of purge eliminated because 24 hours of dual swab airlift pumping is not required. **Disadvantages/Risks:** • Gravel pack not included so sand production may occur but could be mitigated by installing a sand separator on discharge piping if necessary. • Jetting/E-C issue not specifically addressed which could lead to damage to liner screen, but with no gravel pack, it would not enter and be pumped from the well. • If problems develop, then well replacement may be necessary; current cost estimates for a new well are at approximately $3M.

(1) Tasks have been added to the recommended technical approach since discussions were conducted with the NASA Remedial Project Manager (RPM) on January 9, 2012 to further improve the likelihood of success of the recommended technical approach.

3.3 Well 52 Field Activities Summary

Activities associated with Well 52's liner re-installation were performed from July through October 2012. The liner screen and casing were sent to an off-site fabrication facility where all torch-cut ends of pipe were straightened and re-beveled followed by cleaning. The well contractor mobilized to the site on July 30 and 31, 2012 and wire brushed the original well casing (see Figure 39).

Figure 39. Wire Brush

Sediment that accumulated at the bottom of the well was removed with a bailer and was contained in a soil roll-off bin. On August 13, 2012, Longmire swaging installed a 4-foot long "squeeze" patch to cover a hole in the original casing at 223.08 feet (see Figures 40 and 41).

Figure 40. "Squeeze" Patch Installation

Figure 41. "Squeeze" Patch before Install

A video log was performed on August 14, 2012, which confirmed the proper placement of the casing patch prior to the installation of the liner (see well inspection log presented in Attachment 5). The re-fabricated liner was installed into Well 52 from August 15 through August 17, 2012. The liner consisted of the same

material that was previously installed in the well with the exception of two blank casing sections and eight screen sections that were replaced with new Roscoe Moss material due to the damage incurred during the 2011 removal activities. The liner consisted of 252.14 ft of 16 5/8-inch outer diameter 5/16-inch thick blank high-strength low alloy casing (including a 5-ft long dielectric coupler), and 360 ft of 16 5/8-inch 304L stainless steel wire-wrapped screen (0.070-inch slot size). The liner was hung inside of the original casing and was anchored by three 6 in. × 1 5/8 in. × 1 in. welded gussets (see Figures 48 and 49). No gravel pack was installed in the annular space between the original casing and the liner. A video log was performed on August 20, 2012 prior to the pump installation and a well inspection report is presented in Attachment 5. Table 2 summarizes Well 52 liner construction details, and a liner installation summary is provided in Attachment 8. Liner installation photos are presented in Figures 42 through 51. The Well 52 liner diagram is presented in Figure 52.

Figure 42. Liner Joint Weld

Figure 43. Hoisting Liner Screen

Figure 44. Blank Casing and Screen

Figure 45. Liner Screen and Blank Casing

Figure 46. Welding Screen Joint

Figure 47. Well 52 Site Overview

Figure 48. Welding Gussets

Figure 49. Gussets Close-up

Figure 50. Fire Suppression (Wetting Work Area)

Figure 51. Completed Liner

Table 2. Well 52 Liner Construction Details (2012)

Well ID	Completion Date	Depth (ft bgs)	Depth to Water (ft bgs) (9/19/2012)	Diameter (inches)	Well Casing	Liner Blank (ft bgs)	Liner Screen* (ft bgs)	Screen Slot Size
Well 52	2012	612.14	120.11	16.63	High strength low alloy	0.00 – 252.14	252.14 - 612.14	0.070

* 304L stainless steel wire-wrapped screen

Battelle

Well Liner Diagram
Pasadena, California
WELL-52

State Well ID#: 1910124-021	Site: City of Pasadena (MHTS)	Well #: WELL-52	Northing: 1893789.615
Rehabilitation Contractor: Layne Christensen	Well/Liner Diameter: 20.00-inch/16.63-inch	Liner Install Date: 8/13/12 - 8/17/12	Easting: 6510947.930
Reviewed by: D. Conner	Installer/Welder: M. Evans/G. Frias	Geologist: D. Conner	Surface Elevation: 1076.76'

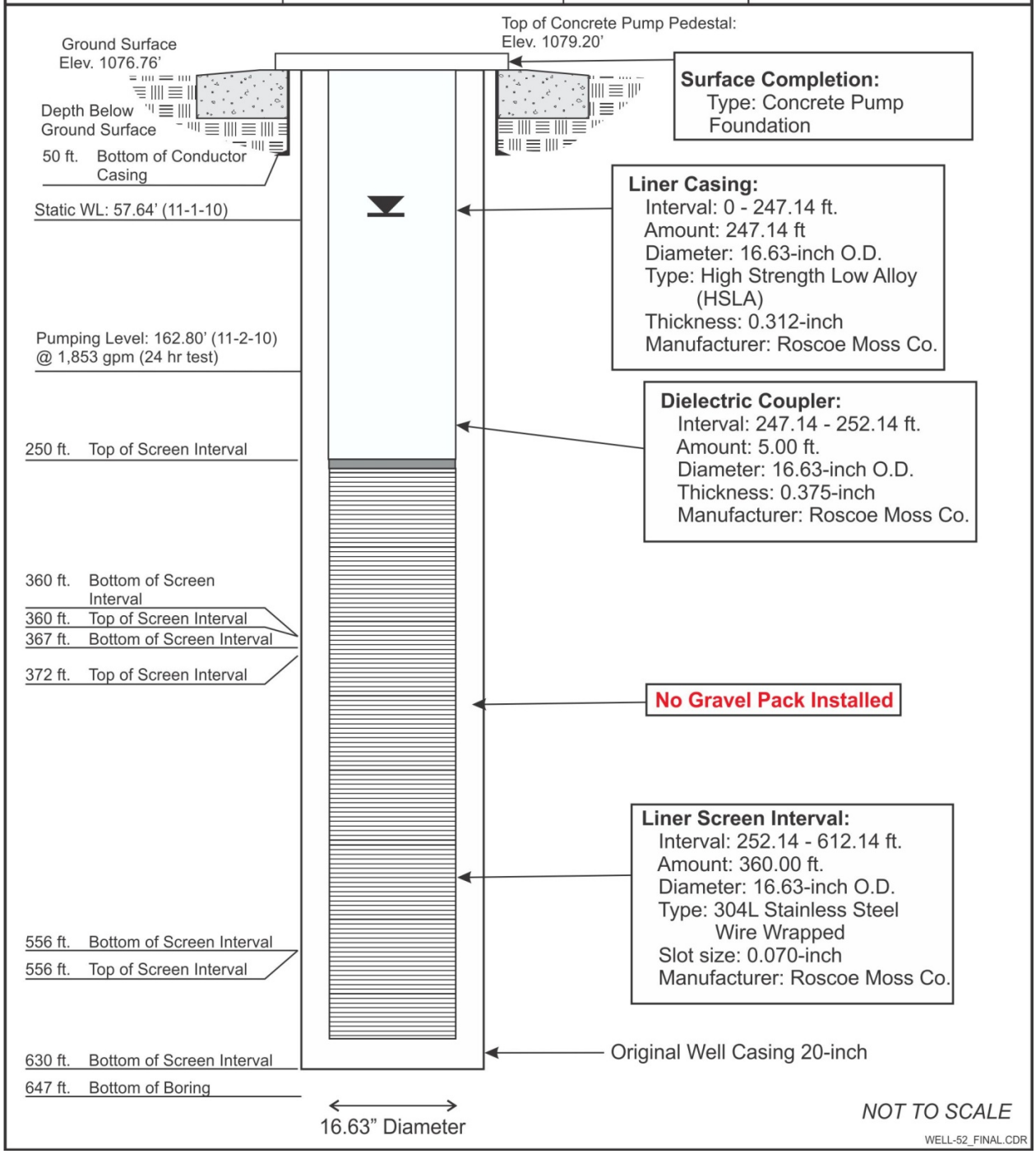

Figure 52. Well 52 Liner Diagram

Next, the rebuilt four-stage pump with cast iron, glass-lined bowls and silica bronze impellers were installed into the well from August 20 through 24, 2012. During the pump installation, two 1-inch polyvinyl chloride (PVC) pipes and one stainless steel airline were strapped to the pump column with stainless steel straps and extended from the pump pedestal flange to the top of bowls (247.00 ft). Table 3 presents Well 52's pump specifications. On August 30, 2012, a temporary pipeline was installed running from Well 52's discharge piping to the MHTS spreading basin discharge point by Rain for Rent (see Figure 53). The well was disinfected on September 18, 2012 followed by well startup and de-chlorination on September 19, 2012. Extracted groundwater from Well 52 was de-chlorinated and blended with treated water from the MHTS prior to being discharged to the spreading basins. The well passed bacteriological testing on September 20, 2012, and on September 26, 2012, Well 52 resumed pumping to the MHTS for drinking water production. Pump startup field logs are presented in Appendix 10. Rain for Rent removed the temporary pipeline and the well contractor cleaned up and demobilized from the site on October 1, 2012.

Figure 53. Well 52 with Temporary Discharge Piping

Table 3. Well 52 Pump (2012)

Well ID	Pump Setting Top of Bowls	Pump Intake	Motor Horsepower	Design Flowrate
Well 52	247.00	261.92	200	1,800

3.4 Windsor Field Activities Summary

Activities associated with Windsor's liner re-installation were performed from August through October 2012. The liner screen and casing were sent to an off-site fabrication facility where all torch-cut ends of pipe were straightened and re-beveled followed by cleaning. The well contractor mobilized to the site on

August 2, 2012 and wire brushed the original well casing. Sediment that accumulated at the bottom of the well was removed with a bailer and was contained in a soil roll-off bin. Containment equipment consisting of a tube settler tank, three 21,000 gallon containment tanks; a skid mounted bag filter unit, two transfer pumps, and associated hoses and fittings (see Figure 54) was mobilized to the site in mid August.

Figure 54. Rain for Rent Containment Tanks and Filter; Windsor Work Site

A video log was performed on August 20, 2012 prior to the installation of the liner (see well inspection log presented in Attachment 5). The re-fabricated liner was installed into the Windsor Well from August 28 through August 31, 2012, and a liner installation summary is presented in Attachment 8. The liner consisted of the same material that was previously installed in the well with the exception of two blank casing sections and three screen sections that were replaced with new Roscoe Moss material due to the damage incurred during the 2011 removal activities. The liner consisted of 319.83 ft of 14.50-inch outside diameter (O.D.), ¼-inch thick blank, high-strength, low alloy casing (including a 5-ft long dielectric coupler for connecting dissimilar metals), and 269.12 ft of 14.50-inch 304L stainless steel wire-wrapped screen (0.080-inch slot size). A 312.14-foot long, 1.50-inch steel gravel fill tube was welded to the blank section of the liner as it was installed into the well. Figures 55 through 60 present photos of liner installation activities. Table 4 provides a summary of well liner construction details.

Tacna Sand and Gravel 1/4 × 16 engineered gravel pack was gravity fed into the annular space between the original casing and the liner (see Figure 62). The engineered gravel pack sieve analysis is presented in Attachment 9. This was followed by single line swabbing to consolidate the gravel pack. Gravel depths in the annular space were monitored during swabbing and gravel was added accordingly. Following the single line swabbing, dual swab airlift pumping (DSAL) was completed in 10-foot increments throughout the screened zone to further consolidate and develop the well (see Figures 63 and 64). Over a three day period, 30,800 gallons of water were removed from the well via DSAL pumping. Daily pumping field logs are presented in Attachment 10. Following the DSAL pumping, another video log was completed; a copy of the well inspection log is provided in Attachment 5. Following the video log, the gravel pack was

topped off, and the completed gravel pack interval was 301.14 to 591.14 feet bgs. Next, a 10-foot thick transition sand consisting of RMC Pacific Materials Lapis Lustre #1C was gravity fed into the annular space between the original casing and liner from 291.14 to 301.14 feet bgs. A cement seal was emplaced on top of the transition sand via concrete pump and tremie pipe and was allowed to set (see Figure 65). The cement seal was installed to prevent the flow of water from entering the hole in the original well casing (see Figure 23). A liner installation summary is provided in Attachment 8. The Windsor Well liner diagram is presented in Figure 61.

Table 4. Windsor Well Liner Construction Details (2012)

Well ID	Completion Date	Depth (ft bgs)	Depth to Water (ft bgs) (10/31/2012)	Diameter (inches)	Well Casing	Liner Blank (ft bgs)	Liner Screen* (ft bgs)	Screen Slot Size
Windsor Well	2012	591.14	203.60	14.50	High strength low alloy	0.00 – 322.14	322.14 - 591.14	0.080

*304L Stainless Steel Wire-wrapped Screen

Figure 55. Blank Liner Casing

Figure 56. Liner Blank and Screen Casings

Figure 57. Liner Installation

Figure 58. Screen Joint and Centralizers

Figure 59. Blank Casing and Gravel Fill Tube

Figure 60. Liner Surface Completion

Battelle

Well Liner Diagram
Pasadena, California
WINDSOR-48

State Well ID#: 1910124-022	Site: City of Pasadena (MHTS)	Well #: WINDSOR-48	Northing: 1892155.945
Rehabilitation Contractor: Layne Christensen	Well/Liner Diameter: 20.00-inch/14.50-inch	Liner Install Date: 8/27/12 - 9/14/12	Easting: 6511051.010
Reviewed by: D. Conner	Installer/Welder: M. Evans/G. Frias	Geologist: D. Conner	Surface Elevation: 1153.86'

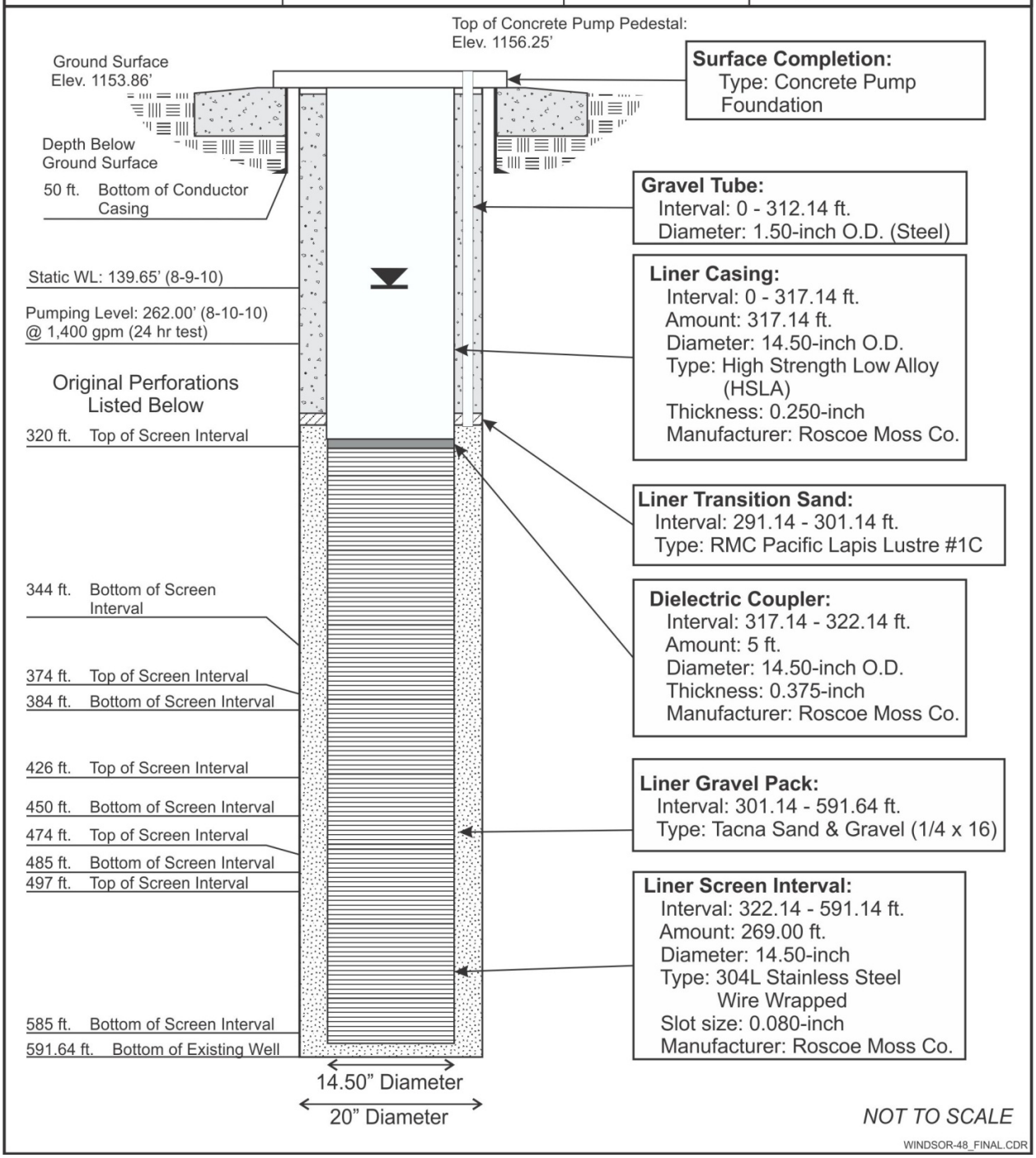

Figure 61. Windsor Well Liner Diagram

Next, the rebuilt nine-stage pump with cast iron, glass-lined bowls and silica bronze impellers were installed into the well (see Figures 66 and 67). Well 52's pump specifications are provided in Table 5. During the pump installation, two 1-inch PVC pipes and one stainless steel airline were strapped to the pump column with stainless steel straps and extended from the pump pedestal flange to the top of bowls. Following the pump installation, the well was disinfected on September 24, 2012 followed by well startup and de-chlorination on September 27, 2012. Figures 68 and 69 show Windsor's pump and discharge piping. Extracted groundwater from Windsor Well was de-chlorinated and blended with treated water from the MHTS prior to being discharged to the spreading basins.

During pumping operations, the pumping water level (PWL) was observed at the top of the bowls (307.00 feet) and the water was aerated; the pump was shut down due to inadequate pump submergence. On October 1, all containment and filtration equipment was demobilized from the site. On October 2, 2012, the pump was lowered by the well contractor an additional 80 feet to a depth of 387.00 feet. A second well disinfection was performed, and well startup and de-chlorination were performed on October 4, 2012. Extracted groundwater from Windsor Well was de-chlorinated and blended with treated water from the MHTS prior to being discharged to the spreading basins. During pumping operations, discharge water was aerated and the PWL was observed at the top of bowls (387.00 feet) and the pump was again shut down due to inadequate pump submergence. It should be noted that the static water level recorded on October 4, 2012 (196.23 feet) was 56.58 feet lower than the static water level recorded on August 10, 2010 (139.65 feet). The well was again operated on October 31 and November 2, 2012 in which sufficient pump submergence was maintained with the Cla-Val pressure sustaining valve set at 130 pounds per square inch of backpressure. Pump discharge water was heavily aerated and the well contractor recommended that the pump not be operated until basin water levels increase. During both pumping events, discharge water was blended with treated MHTS water prior to discharge to the spreading basins. Pump startup field logs are presented in Appendix 10.

Table 5. Windsor Pump (2012)

Well ID	Pump Setting Top of Bowls	Pump Intake	Motor Horsepower	Design Flowrate
Windsor	387.00	396.50	250	1,400

Figure 62. Gravel Pack Installation

Figure 63. DSAL Pump Installation

Figure 64. DSAL Pumping

Figure 65. Concrete Seal Installation

Figure 66. Pump Delivery

Figure 67. Pump Installation

Figure 68. Windsor Pump and Discharge Pipe

Figure 69. Windsor Pump and Discharge Pipe